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Assessment of Building Failure: The Case of Saint Thomas's Anglican Church, Akure, Nigeria

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ABSTRACT: *There have been incessant reports of the collapse of buildings resulting in the loss of lives and properties globally. However, there has been a dearth of information regarding any findings about the collapse of building structures. An extensive study of causes of selected building collapse in Nigeria and abroad is carried out in this work by visiting some locations of building collapse, reading journals and newspaper articles on structural defects and testing rubbles collected from collapsed areas. This study therefore examined the general causes of the collapse of some buildings particularly the reasons for the collapse of Saint Thomas's 2-storey Church Hall, Akure. Laboratory testing was carried out in this study to investigate the causes of collapse using samples from the site of the collapsed building. An appraisal of the structural drawings of the collapsed building was also investigated. Findings revealed that the building collapsed due to poor design, bad construction materials and inadequate supervision. The paper concludes that buildings collapse can be reduced in Nigeria by avoiding all. It recommended use of only duly registered professionals in the building industry for construction.*

KEYWORDS: *Akure, building failure, poor design, construction materials, St. Thomas's Anglican Church*

I. INTRODUCTION

A structure is a whole building, complex, framework or essential part of a building. Marshall and Nelson (1981) defined structure as a body capable of resisting applied loads without any appreciable deformation of one part relative to another. In a simpler form, a structure is that which carries load and transfers the load from the point of load application to the point of load support. The structure of the building is therefore that part of the building construction, which gives the construction sufficient strength to withstand the load to which the whole building in subjected. A building structure does this by carrying the load imposed on it and transferring them safely to the foundations and hence into the ground. There are two broad sub-divisions of the structure. The first type is the framed structures, which resist applied loads by virtue of their geometry. The second type is the mass structures, which resist applied loads by virtue of their weight. According to McGinley (1998), buildings are utilized primarily for living, working and storage. He further categorized them into three broad types. The first is the monumental structures which comprise the churches, city halls and sports arena. The second is the institutional structures represented by the more usual kind, such as block of flats, tertiary institutional buildings for academic and administrative purposes. The third group comprises the industrial structures represented by the ordinary small-scale industrial types. Ogunsemi (2002) disclosed the basic requirements that a building must satisfy. Every member of a structural system should be able to resist, without failure or collapse, the applied loads under the service conditions. In other words, it must possess adequate strength. This demands that the materials of the structure must be adequate to resist the stresses generated by the loads. The shape and size of the structure must be adequate also. The components of the structure should be able to resist deformation under loading conditions. Deformation implies a change in size or shape when a body is subjected to stress. This means that the component should possess adequate stiffness. Thus, the stiffness of a beam or column is a measure of its resistance to bending or buckling. A material or structure that is very strong but lacking in stiffness will so much deform that it will not be able to resist the applied loads. All the structural members of the building must be stable, otherwise the whole structure will be assumed unstable. Structural stability is needed to maintain shape since it is the ability of a structure to retain under load, its original state of equilibrium. It can mean anything from resistance to a minor degree of movement to resistance to sliding, overturning, partial or complete collapse. Any phenomenon that can alter the load carrying behavior of a structure, if not properly taken care of can lead to instability, a condition in which the support reaction is less than applied load, thus to ensure stability, loads must be balanced by reactions and the moments due to loads must be balanced by the moments due to reactions. Any building that cannot withstand the load applied to it will show signs of distress, which may lead to failure and invariably total collapse.

Nigeria has witnessed in the recent times a number of collapse of buildings in some cities. When buildings collapse, they create deep emotional reactions from every segment of the population. Consequently, very rigorous attempts have been made by various professionals connected with building construction to identify the causes of the collapse of buildings. However, failure of structural members and foundation of buildings, which normally

lead to collapse in most cases have began since the inception of technology materials. The news of collapse of buildings has always been on the increase in the Daily News Papers, not only in Nigeria but also in various parts of the world. The collapse of the Saint Thomas's Church Hall, 2-storey building, Arakale Akure, which was used as a case study in the project occurred on the 30th of September in 1998. The tragedy, which killed and injured several people drew the attention of Government functionaries, Engineers and other professionals from within and outside the State to sympathize with the state government and members of the Church. Since there was no investigation to the causes of the collapse in order to guard against future occurrence, the paper intends to determine the real causes of the collapse. This study shall provide answers to the following questions:

1. What are the causes of the collapse of Saint Thomas's 2-storey Church Hall, Akure?
2. What are the possible solutions to building collapse in the study area?
3. This study is organized into five sections: literature review, methodology, data analysis, results and discussions, and conclusions.

II. LITERATURE REVIEW

Retrospectively, Powell and Billington (1984) defined building as any permanent or temporary structure and, unless the context otherwise requires, it includes any other erection of whatever kind or nature. On the other hand, buildings are enclosures for spaces designed for specific uses meant to control local climate, distribute services and evacuate wastes. They exist to meet the primary physical human needs of shelter. They are seen as structural entities capable of securing self and applied weights on to the ground.

Past records have shown that the early man's methods of constructing shelters are quite different from those of the modern technological era.

Izoma (2001) admitted that shelter represents one of the most basic human needs and has no doubt a profound impact on the health, welfare and productivity of the individual. In spite of its importance, there is unfortunately a universal shortage of desperately needed dwelling units. The methods used by the early men to build their house could be criticized to some extent. Though the period is referred to as the dark ages, when modern technological inventions and discoveries were yet to be made. A house built with mud block, as a matter of fact, without good concrete foundation is not durable. Also, during that period cement had not been in existence. The moment there are cracks generated on the walls because of differential settlement could easily lead to endangering the lives of the users. In the event of serious rainstorm and wind, the house built with mud, bamboo and palm trees will not stand the tests of time. Such houses are not conducive for living. Any time there is an outbreak of fire; these houses could be easily burnt, destroying lives and properties. However, the early man's methods of building their houses were dangerous and risky to lives and properties.

Syal and Goel (1993) disclosed that most of the structures in the past were made either in masonry, steel or timber depending upon the availability of the materials and the nature of the structure. Very recently, concrete, as building material, has come into existence. In a short period, concrete has gained so much importance that today more than 65 percent of the structures coming up in the world are constructed with concrete. During the Gothic period of Architecture (1100-1500 A.D.) churches with pointed arches ribs supported by stone pillars strengthened by buttresses. These structures led to the idea of framed structures. The great pyramid is one of the most extraordinary works of Architecture ever executed. Approximately, two thirds the size of Hoover Dam, it stood for more than four millennia as the largest man-made structure on earth, rising to a height of 137.4m from the base that was carved from the solid bedrock of the Giza plateau that covers 5.2 hectares and constructed of an estimated 2 million blocks of lime stones and granite. However, failure of structural members and foundation of buildings, which normally lead to collapse in most cases have begun since the inception of technology materials. The news of collapse of buildings has always been on the increase in the Daily News Papers not only in Nigeria but also in the world as a whole Records have shown recently that multi-storey buildings collapsed in Lagos, Ibadan, Kano, Kaduna, Akure and many other Towns in Nigeria where so many people lost their lives. These have also happened in various parts of the world.

Historically, the site of the collapsed building as reliably gathered from the reports of the questionnaire returned is a built-up area. A built-up ground is a refuse, excavated rock and soil deposited for the purpose of filling a deep depression valley and gorge or for raising the site above its natural level. The site terrain was initially undulating and sloppy. Part of the site was originally a swampy area but later reclaimed and developed. A building was first constructed on the site using mud block in the early 1960 which was used as classrooms by Saint Thomas's Primary School and Sunday School by the Saint Thomas's Church. The partitions in the building were later removed to convert the whole building to a place of worship. The building was later demolished and the place was left open for many years before the plan to build this collapsed Church hall came up.

The 2-storey framed structure collapsed after the casting of the 2nd floor slab on 30th of September 1998. There were some signs noticed prior to the collapse. Concreting of the 2nd floor slab had already been completed that day when suddenly the pillars at the ground floor started making sounds of strains, particles of concrete columns started wangling and twisting. Also, buckling of the steel at the base, crushing of materials and concrete cover giving way exposing the column reinforcement which are caused by overloading were noticed. Eventually, sound of explosion perhaps, after reaching the yield point occurred.

The architectural and structural designs of the collapsed building were done by FUTA ventures Limited at the Federal University of Technology, Akure. The building was designed for a single storey building. During the construction, the number of floors was increased to two to become a two-storey building without any corresponding modification to the structural design. Simire (2001) disclosed the collapse of a three-storey Mosque building, where so many people died because of a heavy rain downpour. The structure was located at Buhari Street, Mushin, Lagos and collapsed on 20th April, 2001. It was gathered that the structure was formerly a bungalow and that the addition of one floor was too much for the foundation, which was not initially designed to carry such a load.

Aderibigbe (2001) reported the collapse of a four storey structure located at Akewusola Street, off Oduduwa Street, Oworosonki, in the Kosofe Local Government Area of Lagos State. The incident claimed at least one life with three others seriously wounded. According to the report, the structure was initially built as a bungalow without an approved building plan. Information revealed that the addition of more floors led to the collapse before the completion. Also, it was gathered that the landlord of the house was the Architect, the builder and the supervisor. Table 1 shows details of some collapsed buildings in Nigeria and around the world.

Table 1: Some Collapsed buildings in Nigeria and Abroad. (1977 – 2003)

S/N	Type of Building Structure	Location of Building	Failure Collapse Date	Suspected Causes	Remarks
1	Residential Buildings	Bamawa Housing Estate, Kaduna, Kaduna State	August 1977	Faulty Design	28 People died
2.	One Storey building	75, Ijoka Road Oluwatuyi Qtrs, Akure	1982	Under-Reinforcement, Lack of Qualified Professional to supervise	No Casualty
3	One Storey Building	12, Gbogi Street, Akure	August 1983	Fire disaster	2 died
4	4-storey Commercial Building(LACCO)	Oba Adesida Road, Akure	October, 1983	Fire disaster	No casualty
5	Residential Building	Adeniji Adele, Lagos	January, 1985	Excessive Loading	2 died including Owner
6	Uncompleted 4-storey building	Aponri, Lagos	May 20, 1985	Structural Failure	13 people Reported dead
7	One-strey Building	14, Ayegunle Street Off Arakale, Akure	1985	Foundation Problem	No casualty, Occupant already Abandoned the Building
8	Residential Building	Idusagbe lane, Idumota Lagos	September 14, 1987	No structural Design	17 people died 12 persons Injured
9	School building	Diobu, Port Harcourt	April, 1990	No structural Design and Approval of Town planning	Over 50 people Reported dead
10	One storey (Mud building)	6, Stadium Road, General Hospital Ondo	May, 1999	Lack of Reinforced Structural members	No casualty

11	One-storey building	4 Oke-Bola St., Ado Ekiti	1999	Fire disaster and dereliction of the building	No casualty
12	One-storey building	Bishop's Court Diocese, Ife Road, Ondo	1999	Under-reinforcement, poor workmanship improper supervision	No casualty
13	One-storey building	No. 23 Odi Olowo, Akure	1999	No site Investigation And foundation problem	Sank and Collapsed but no casualty
14	2Nos, One-storey building	Owa Ale of Ikare, Ogbagi Street, Ikare	2001	Fire disaster	No casualty
15	One – Storey Residential building	69, Odo Koyi, Akure	September, 2001	Foundation Problem	No casualty
16	Many buildings	Odoso compound, Ikare	February, 26 2002	Fire disaster	No casualty
17	One-storey Building (Ogbo's House)	16, Oyemekun road, Akure	Nov. 22, 2002	Fire disaster	No casualty
18	Methodist Primary School building	12 Methodist Church, Road, Gbogi, Akure	16 April, 2003	Rain storm	No casualty
19	Church building Porch deck.	15, Ojuelegba, Akure	April 25, 2003	Poor workmanship and under-reinforcement	No casualty
20	Portal framed structure	Onyearugbulem market, Akure	May 2003	Poor workmanship and under-reinforcement of the cantilevering end	No casualty
21	Residential buildings	Saravyero Yugoslavia	November, 1978	Earthquakes	1,160 people died
22	Commercial building	Mexico City	15th September, 1985	Structural failure as a result of Earthquakes	Many died
23	Juarez Hospital Framed structure	Mexico City	1985	Localized Failures at the Beam-to-beam Joints of each Floor	400 medical personnel and patience were trapped
24	A luxury apartment block	Alexandria	1992	Structural Failure	20 people died
25	Two separate buildings	Egypt	1992	Structural failure	30 people died
26	Buildings collapse	Turkey	March, 1992	Twin Earthquakes	Over 4,000 People died
27	Café and coffee House and many others	Jerusalem, Israel	March, 1992	Mudslides caused by some of the same unusual weather that caused blizzard and flood in the middle east	Over 20 People were killed

28	Israel Embassy	Argentina	March, 1992	Car Bomb donated by Islamic Jihad	More than 27 people died
29	A Tower and Many office Buildings	Sanferrado valley, Northern Los Angeles	17th January, 1994	Earthquakes	57 died and 1,500 injured
30	Apartment block	Foggia, Rome	December, 1998	Structural failure	17 people died
31	World Trade Centre	Washington DC, America	11th September, 1999	Terrorist Attack	Over 1000 People dead
32	Many tall buildings	Paraguay	9th Nov. 2001	Earthquakes	125 people Dead
33	Many buildings	Brazil	16th February, 2002	Seismic forces Due to Earthquakes	Over 1000 People dead
34	School building	Turkey	18th April, 2003	Earthquakes	Over 200 students died
35	Partially built supermarket	Southern city of Jiangmen, China	8th October, 2003	Structural problem	More than 10 People died, 5 People missing, 5 people injured
36	10-storey Atlantic City Garage	Atlantic City, South Jersey, America	30th October, 2003	Cracks developed in the concrete Floor/columns	4 people died and 21 persons injured
37	A 3-storey church Under Refurbishment	1713 Arctic Avenue, Atlantic City, U. S	9th November, 2003	A steel Support brace gave out	No death recorded

Sources: Fakere, Fadairo and Fakere (2012); Ogunsemi (2002); Nigeria Daily News Papers (1977-2003)

III. METHODOLOGY

In order to fulfill the objectives of this research, some collapsed building locations were visited in Akure, Ikare, Ondo, Irele and Ado Ekiti. Physical inspection of various sites where collapse occurred were carried out. Data collected were analyzed to arrive at logical conclusion. Information was collected through Nigeria Daily News papers from 1977 to 2003 and Engineering Journals from where Data on Building collapse were collected to tackle menace of Building collapse in our society. Representative samples of concrete rubbles were collected and analyzed in the laboratory. The tests performed include mineralogy and crushing tests. From these, the compressive strength of concrete and suitability of the building materials were determined for comparison with the standards. The design drawings used for the construction were collected, checked and analyzed. This is to ascertain whether design errors were made from the professional engaged for the design of the collapse building of St. Thomas's Anglican Church Akure.

IV. DATA ANALYSIS RESULTS AND DISCUSSIONS

Mineralogy test: In Table 2, it was discovered that the percentage of Biotite is too high in the construction aggregate materials. Biotite is particularly susceptible to moisture attack. Twidale (1982) pointed out that in an environment exposed to moisture, mica takes water into its lattice and expands, particularly along basal cleavage. The fractures developed in the expanded biotite extend as micro-fissures through adjacent quartz and feldspar crystal. The biotite is altered to hydrobiotite. The chemical changes are slighting involving oxidation of iron II to Iron III and the replacement of potassium by water molecules. This leads to expansion and distintegration. When this problem occurs, the concrete is weakened and eventually leads to structural failure. In the mineralogy test carried out on the Aggregate used for the construction of the structural members of the collapsed building, sample A contains 70% feldspar, 8% muscovite, 6% Biotite, and 6% Quartz, 4% Mont morillonites, 3% kaolinite and 3% Illites. In sample B, Quartz is 60%, Biotite is 30% and Muscovite is 10%. In Sample C, the dominant is mainly Biotite with minute accessories of muscovite and quartz. From the above analysis, Biotite is considered

to be the most dominant mineral of the granite material followed by feldspar and muscovite. However, we can conclude that Biotite is dominant of the aggregate used for the construction of the collapsed building and therefore one of the factors that led to the failure of the structural members of the building.

Table 2: Mineralogy Test

Sample	Minerals	Percentage (%)
Sample A Granite but feldspathic	Feldspar Muscovite Quartz Biotite Montmorillonites Kaolinite Illites	70 8 6 6 4 3 3
Sample B Porphyritic Granite but Quartzitic	Quartz Biotite Muscovite	60 30 10
Sample c Charnockitic	Mainly Biotite with Minute particles of Muscovite and quartz	Over 80% Biotite

Compressive strength of concrete : In Table 3, the average crushing strength of 4.9 N/mm^2 is obtained. This value is too much below the cube strength expected for ratio 1:2:4 mix design after 28 days of curing. Though the concrete samples collected for testing had been exposed in the atmosphere for 4 to 5 years which invariably might have reduced the crushing strength of the concrete. Also, the effect of the collapse would also have reduced the strength of the concrete. Notwithstanding, the value would not have been reduced drastically. Higher result should have been obtained. It could be remarked that mix ratio of the concrete material used for the construction was obviously less than 1:2:4 mix ratio.Therefore, it could be concluded that the workmanship during the construction of the collapsed building was poor. This in fact must have contributed to the weak structural members like columns, beams and slab, which led to the collapse of the building. Tomilinson (1980) pointed out that the principal cause of deterioration of concrete in foundation is attack by sulphates present in the soil, in the ground water or in sea water. Other agencies causing deterioration include chemical waste, organic acids, frost, sea action, certain deleterious aggregates and corrosion of reinforcement. All these could reduce the strength of concrete and eventually lead to collapse of building. It was alleged that vibration machine was not used during the casting of the concrete works in the collapsed building. Also, insufficient cover in the structural members would have led to corrosion of reinforcement in the concrete. All these amounted to poor workmanship as part of the principal factors that led to the collapse of the building.

Table 3: Compressive Strength of Concrete

Cube No	Age of testing	Date tested	Weight of cube (gm)	Density Kg/m^3	Crushing Load (N)	Crushing strength N/mm^2
A	Over 28 days	18/12/03	4958	8471	20,000	5.2
B	"	"	3630	6694	15,000	2.8
C	"	"	4150	6072	20,000	3.6
D	"	"	4170	6043	15,000	3.2
E	"	"	3040	7737	5,000	6.9
F	"	"	6658	4326	15,000	3.8
G	"	"	2795	3864	3,000	6.2
H	"	"	2870	4014	5,000	4.9
I	"	"	3590	4308	3,000	7.0
J	"	"	3504	2354	5,000	5.8

Average Crushing Strength = 4.9N/mm^2
Standard value Range = 21 – 22 N/mm^2

Checking of the Selected Beams : The structural design and detailing of the collapsed Saint Thomas's Church Hall was carried out by FUTA Ventures of Federal University of Technology, Akure. The Beams and columns

layout are shown in figure 1. In Table 4, all the beams checked were normally reinforced except beam eight, which was over-reinforced. An over-reinforced section, which fails in flexural compression, contains more reinforcement than is required to give a balanced section. As the applied moment is increased, the concrete attains its ultimate stress value first, so that by the load is increased continually, since overstress in concrete occurs earlier than in reinforcement any failure is sudden. The depth of the compression zone is increased to a value greater than the balance section. An under-reinforced section on the other hand which fails in flexural tension contains too little reinforcement to permit the balance section to be developed. In under reinforced section, cracks open when the stresses in tension reinforcement attain yield value. The depth of the compression zone is reduced to a value lower than the balance section. In this case since less material is used and besides since when overstressed the reinforcement yields, it is still able to support the yield stress, failure here is gradual. The depth to the central axis is less than the Balance section. In order to determine whether a section is over-or-under reinforced therefore it is necessary to calculate the position of both the balanced and the actual neutral axis considering or to compare the total area of reinforcement divided by the product of width and depth with the values specified by B. S. 8110 (1995).

From the reports collected, the failure of the collapse building started from the columns. This occurred within the 30 seconds prior the collapse as the columns started twisting, wangling and buckling with the throwing of stones from the existing columns and removal of the cover provided in the columns. According to Mosley and Bungey (1982) short columns usually fail by crushing and slender column is liable to fail by buckling. If the failure started from the columns as indicated above, most of the columns must have been wrongly designed. Perhaps, all were designed as short columns. Hence, columns three and four about 25 numbers, which should have been designed as slender columns would fail by buckling. We can deduce that part of the reasons of the collapse are buckling of the columns due to overloading of the few columns provided and over-reinforcement of some of the structural members. Also, the addition of one floor to the one storey designed during construction would have some effect on the foundation base. Overloading would cause the earth pressure of the foundation base to increase and bending failure of the columns base would occur. In Table 4, all the beams checked were normally reinforced except beam eight, which was over-reinforced.

Table 4: The Summary after checking the selected beams Designed by FUTA ventures

BEAMS SELECTED	REMARKS
6	Normally Reinforced
7	Normally Reinforced
8	Over – Reinforced
9	Normally Reinforced
12	Normally Reinforced
13	Normally Reinforced
14	Normally Reinforced
15	Normally Reinforced

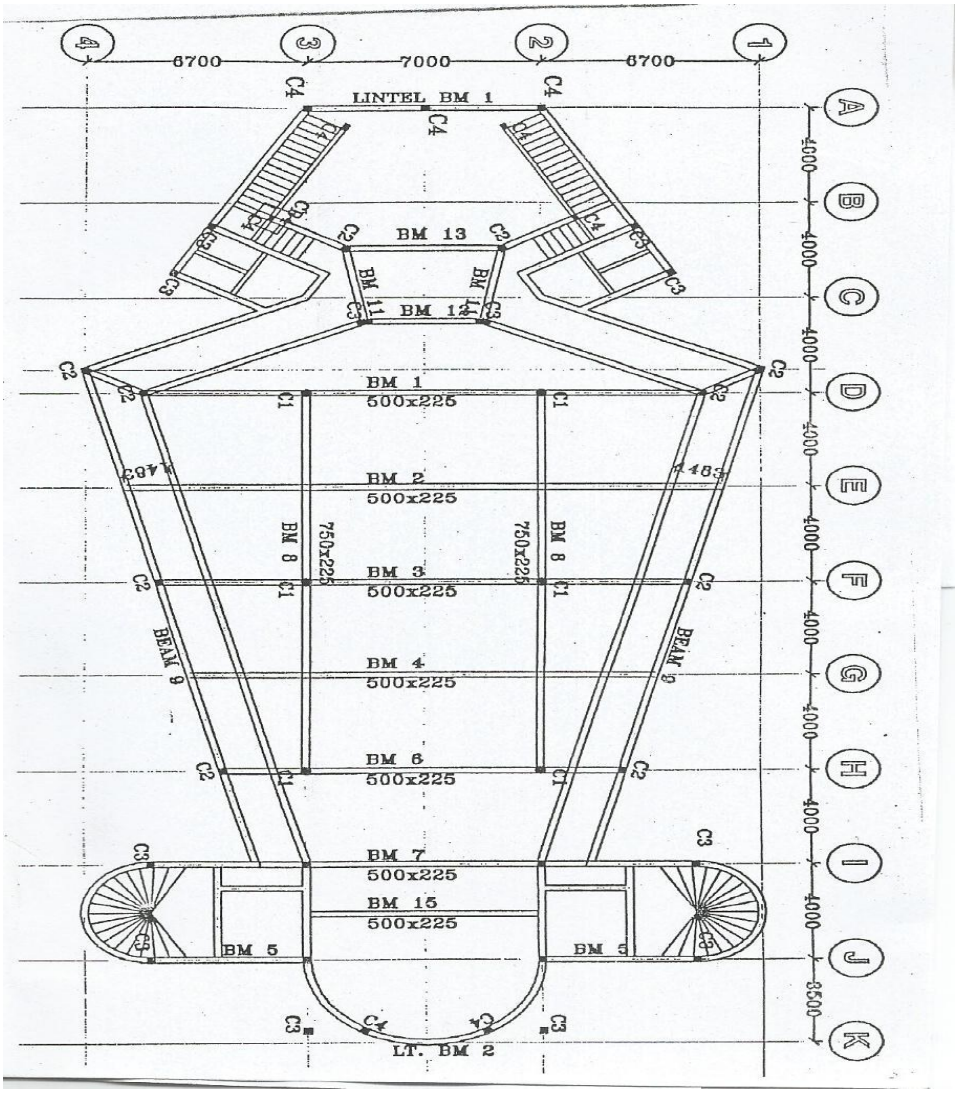

Figure 1: Beams and Columns Layout of the collapse St. Thomas's Church Hall.

V. CONCLUSION AND RECOMMENDATIONS

The causes of building collapse generally may be attributed to a number of reasons among which are lack of town planning approval, alterations to the approved design, negligence to specification, ignorance and greed on the part of the client and contractors, lack of proper soil investigation of the soil, poor quality design, inefficient supervision, inadequate quality control, differential settlement of foundation and wind forces causing lateral deflection. Others are bad quality materials, overloading, poor workmanship, earthquakes, bomb blast and fire disaster. Therefore, the collapse of Saint Thomas's Church Hall, Akure was caused by poor design, poor workmanships, lack of thorough supervision, overloading through the addition of one floor and defect of the coarse aggregated materials. From the conclusion of this study, the followings are some suggestions and recommendation on safe delivery of structures particularly building projects.

[3]. All clients or building developers should be compelled to comply with approved building plans before the construction of their building and that all building construction works should be well designed and supervised by a registered member of Council for the Regulation of Engineering in Nigeria (COREN), Architects Registration Council of Nigeria (ARCON) and Council of Registered Builders of Nigeria (CORBON) Competent registered Contractors should be employed to supervise construction works or projects.

[4]. Regular workshops such as the one by the Nigeria Society of Engineers (NSE) and COREN should be held to improve the professional competence of members.

[5]. There should be a law providing heavy penalties for Contractors who fail to have registered professionals in supervisory capacity in major building projects. Systematic inspection of building works should be

enforced at the Local Government level and penalties for failure to comply with the building standard regulation should be provided for.

[6]. All building construction materials like sand, cement, aggregate, reinforcement bars and particularly foundation soil should be tested before the commencement of any construction. The mineralogy and Alkalinity tests of coarse aggregates should be done to know whether the material contains some percentage of impurities, which are deleterious and injurious to cement and reinforcement rods.

[7]. Government should quickly promulgate a national building regulation for the elimination or considerate reduction of the incessant collapse of buildings in Nigeria and quick response committee for investigating incidents of building collapse should be formed.

[8]. The law governing all approved structural details of buildings, materials and effective supervision by the local Town Planning Authorities should be enforced and not be compromised. Section 2(1) of Ondo State Building and sub division regulations 1984 demands that no building or structure or any part thereof should be erected, converted, altered or enlarged unless a development permit has been obtained by the owner or his agent from the ministry. This provision, which is also contained in section 3(1) of Nigerian Urban and Regional Planning Decree 88 of 1082, should be enforced.

[9]. Government should exercise leadership in protecting and enhancing the quality of all the buildings by encouraging regular maintenance so as to sustain human life.

[10]. All Government functionaries and building developers should be properly trained and encouraged to always give construction of large scale buildings to competent and registered Contractors who will also be supervised by a registered structural engineering Consultant and Architect who preferably have designed such projects.

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